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NASA TM X-68801

STAR 11-5-71

SYSTEM DEFINITION PHASE AND ACQUISITION PHASE PROJECT PLAN FOR SMALL ASTRONOMY SATELLITE SAS-D

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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FACILITY FORM 602
(ACCESSION NUMBER) N72-12858 (THRU) G3
(PAGES) 47 (CODE)
(NASA CR OR TMX OR AD NUMBER) TM (CATEGORY)

N72-12858 (NASA-TM-X-68801) SYSTEM DEFINITION PHASE AND ACQUISITION PHASE PROJECT PLAN FOR SMALL ASTRONOMY SATELLITE SAS-D (NASA) [1971] 47 p CSCL 22B

Unclas
08036 G3/31

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SYSTEM DEFINITION PHASE
AND ACQUISITION PHASE
PROJECT PLAN
FOR
SMALL ASTRONOMY SATELLITE
SAS-D

Acting Project Manager
Donald A. Krueger

This project plan will not be released outside of NASA without the prior approval of the project manager. All funding, manpower and procurement information must be removed before release.

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

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APPROVAL RECORD

Project SAS-D

Issue	Issued by GSFC		Approved by Headquarters		Remarks
	Date	Approving Official	Date	Approving Official	
Sys. Def. & Acquis. Phases	10/1/71	[signature]			

SYSTEM DEFINITION PHASE

AND ACQUISITION PHASE

PROJECT PLAN

FOR

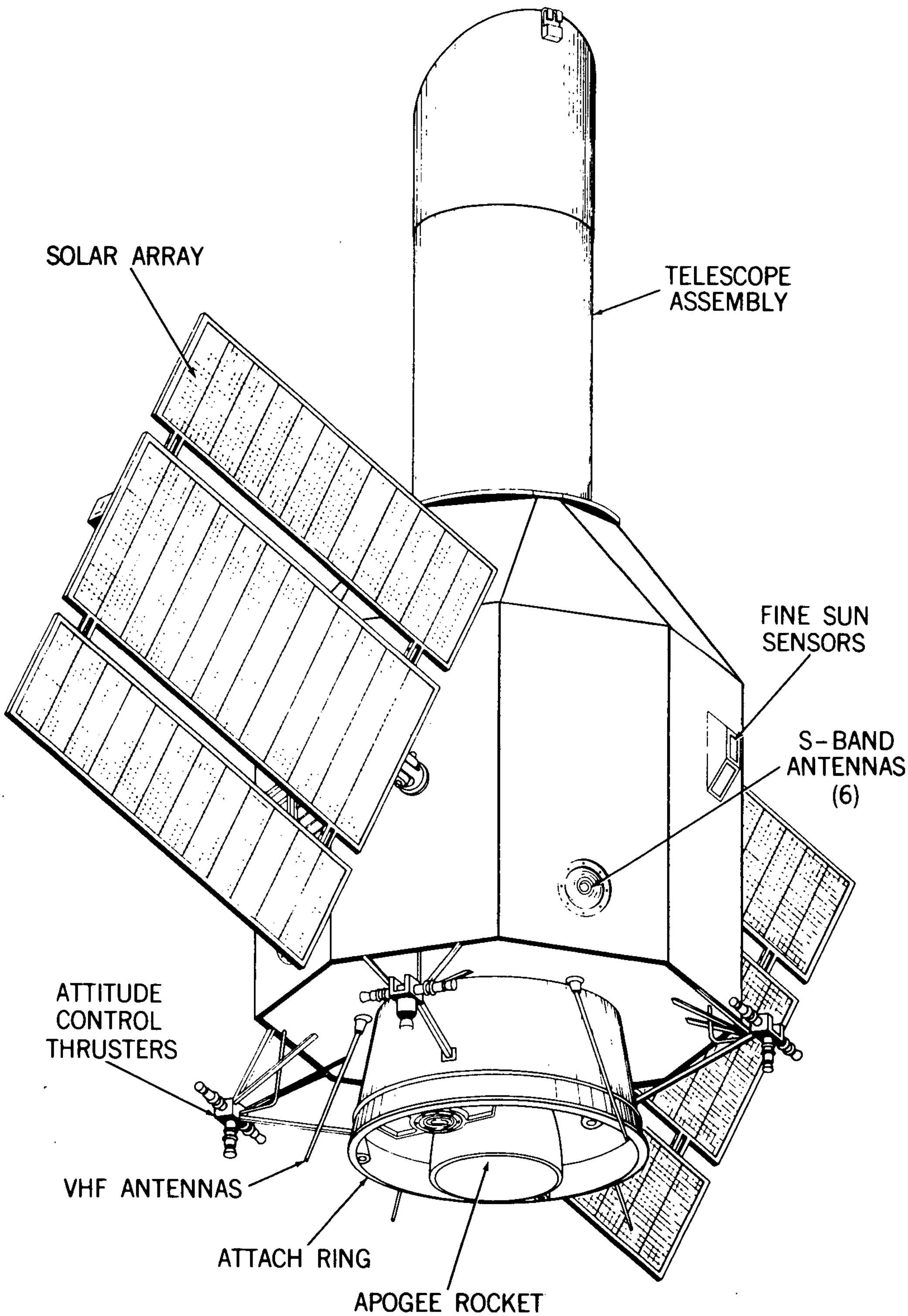
SMALL ASTRONOMY SATELLITE

SAS-D

FOREWORD

This Project Plan for the Small Astronomy Satellite (SAS-D) is Goddard Space Flight Center's plan for accomplishing the project. It is issued in compliance with NASA Handbook NHB 7121.2 and NMI 7120.1, dated May 4, 1970, Subject: Approval and Implementation of Office of Space Science and Applications (OSSA) Research and Development (R&D) Projects. The Project Plan, as approved by GSFC executive management and NASA Headquarters, is the project manager's charter and defines his specific plan of action.

System definition phase activities of the SAS-D Project will be a continuation of the analytical work that established the overall feasibility of the project. The system concept derived from that analytical work is defined in the Phase A (Mission Definition Phase) technical report. System definition phase activities will include detailed engineering analysis and preliminary breadboarding necessary to establish a single project approach from the feasible approaches. This document will be revised at the end of the system definition phase to provide greater detail on acquisition phase planning and to specify a specific system design.



Frontispiece — SAS-D Spacecraft

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SECTION 1

IDENTIFICATION

Small Astronomy Satellite (SAS-D) is the project title designated in the Project Approval Document (PAD), code number 85-850-850-878, July 2, 1971, which authorizes the study and definition of an orbital spacecraft that will obtain spectral-distribution data from celestial ultraviolet sources.

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SECTION 2

PROJECT OBJECTIVES

2.1 GENERAL

The objective of the SAS-D project is to conduct spectral distribution studies of celestial ultraviolet sources using an Explorer-class spacecraft launched by a Delta vehicle into a geosynchronous orbit in the last half of 1975. The telescope system is intended for use by guest astronomers for a major portion of the total observing time. The concept of the overall system, designed to resemble functionally the operation of a ground-based observatory, should maximize the usefulness of the instrument to the astronomical community by limiting the amount of special instruction needed to use the spaceborne telescope. Realization of this objective is important to the desired broad use (both national and international) of the guest-observer concept.

An important justification for the SAS-D mission is the richness of the barely explored spectral region between 1150 Å and 3200 Å. Many resonance lines and other strong lines from the atoms and ions that occur in stellar atomospheres, in gaseous nebulae, in galaxies and in interstellar space fall in this spectral range. Documentation of the apparent strengths and profiles of these lines, whether in emission or in absorption, will lead to fundamental information about the generation of energy by many sorts of stars and how this energy is transferred through the star and radiated to space. Knowledge of the total amount of energy radiated and its detailed spectral distribution will aid in understanding the variety of objects seen in the universe. The SAS-D mission will obtain significant and timely information on what stars, nebulae, and galaxies are and how they develop: that is, answers to some of the primary questions of astronomy and astrophysics.

2.2 SCIENTIFIC OBJECTIVES

Scientific objectives of SAS-D are:

- To obtain high-resolution spectra of stars of all spectral types, in order to determine more precisely the physical characteristics of these stars
- To study gas streams in and around some binary systems
- To observe at low resolution faint stars, galaxies, and quasars, and to interpret these spectra by reference to high-resolution spectra

- To observe the spectra of planets and comets as these objects become accessible

- To make repeated observations of objects known or newly found, to show variable spectra

- To define more precisely the modifications of starlight caused by interstellar dust and gas

2.3 MISSION OBJECTIVES

2.3.1 PRIMARY OBJECTIVES

- To obtain high resolution spectra of the order of 0.1Å in the ultraviolet region of the spectrum from 1150 to 3200Å of stars and planets brighter than 7th visual magnitude, for detailed analyses of stellar and planetary atmospheres in order to determine more precisely their physical characteristics
- To obtain lower resolution spectra (6Å) over the same wavelength range for both stellar and extended objects as faint as 12th magnitude or fainter (15th magnitude) as a function of observing time for investigations of peculiar objects such as quasars, Seyfert galaxies, pulsars, X-ray sources, and variability phenomena to shed light on questions of cosmological significance

2.3.2 SECONDARY OBJECTIVES

- To evaluate the performance of various subsystems and components such as the spectrograph system (in particular image tubes) for potential application to larger astronomical facilities such as the LST

- To provide a basis of utility and experience by combining the operations of a geosynchronous observatory and a ground-based real-time observatory, in order to maximize international and guest observer participation in this mission and to prepare for potential large telescope missions

2.4 HISTORY AND RELATIONSHIP TO OTHER NASA PROGRAMS

The concept of the SAS-D mission is a follow-up and expansion of observations made by the Orbiting Astronomical Observatory (OAO) series of satellites. It will expand astronomical research capabilities to fainter limiting magnitude, in order to pursue questions raised by the OAO data and to investigate properties of the faint nonthermal sources beyond the reach of OAO instruments. It will also provide an opportunity to test several new instruments and operational techniques that are expected to be employed in the Large Space Telescope (LST).

Three basic types of observational information required for ultraviolet (UV) astronomical research are photometry, high-dispersion spectroscopy, and high-resolution imagery. OAO-II is providing the first, and the last must await the advent of the LST. Although OAO-C is designed to obtain spectroscopic data for specific investigations of the interstellar gas, research on the structure and dynamics of stellar and planetary atmospheres (and of other sources such as planetary nebulae and faint galaxies) requires an instrument of more general spectrographic capabilities. This need has been recognized by NASA Astronomy Missions Board (AMB) and by the Space Science Board Committee on the LST; both groups have recommended a series of small or intermediate sized space telescopes, primarily for spectroscopic research. The AMB has further recommended operation of these telescopes as national facilities.

Toward the end of 1969, when further launches of OAO-type spacecraft beyond OAO-C appeared unlikely, GSFC began an informal study to see whether an Explorer-class satellite could meet the programmatic needs of the astronomy program after OAO. This study, based on experience in the SAS and OAO programs at GSFC and on the Ultraviolet Astronomy Satellite study conducted for European Space Research Organization (ESRO) by the Culham group, focused on a system with the following general characteristics:

- Delta launch
- 45 cm UV telescope with an echelle spectrograph
- 3-year lifetime
- Geosynchronous orbit
- Three-axis control
- International (guest-observer) facility

Preliminary investigation indicates that the proposed satellite can provide the desired spectroscopic capabilities. Table 1 compares these capabilities with those of OAO and the proposed LST.

Table 1

Spectroscopic Performance: OAO, SAS-D, LST

		OAO-II	OAO-C	SAS-D	LST (typical)
High Resolution	Bandpass	10Å	0.05Å	0.1Å	0.02Å
	Lim. Mag.	4	5	7*	11*
Low Resolution	Bandpass	100Å	0.20Å	6Å	1Å
	Lim. Mag.	6	5	12*	16*

*Limiting magnitudes calculated for a 30 minute exposure on a B4 star. longer exposures could reach fainter stars

By April 1970; SAS-D capabilities appeared sufficiently encouraging to justify a formal study effort by GSFC. Because the aim of the SAS-D system was to operate primarily as a guest observer facility, GSFC established an astronomy working group early in the study to provide guidance to the project on a continuing basis. Members of this working group represent organizations that had expressed an active interest in conducting astronomical observations from Explorer-class satellites. The members are:

Dr. R. Bless	University of Wisconsin
Dr. A. Boggess III	Goddard Space Flight Center
W. Fastie	Johns Hopkins University
Dr. L. Houziaux	Mons University, Belgium
Dr. D. Morton	Princeton University
Dr. J. Oke	Hale Observatories
Dr. A. Underhill	Goddard Space Flight Center (Chairman)
Dr. L. Wallace	Kitt Peak National Observatory
Dr. R. Wilson	Scientific Research Council Astrophysical Research Unit Culham, England

The working group began by distributing a questionnaire describing the satellite concept to the astronomical community in order to identify potential users, keep them informed of the status of the system, and give them an opportunity to guide its development and operations. The group asked for comments on the observing programs envisaged and system characteristics desired. The questionnaire, distributed in June 1970, has received more than 170 replies which the working group has used to guide the Phase A study effort. These replies, which originated from more than thirty states and fifteen foreign countries, indicate both the broad scientific potential of the system and the widespread interest in its future.

2.5 TELESCOPE & SPECTROGRAPH

The scientific objectives of SAS-D assume a capability of obtaining both high-resolution spectra of bright objects and low-resolution spectra of fainter objects. Determining the equivalent widths of faint lines used to measure chemical abundance, or the profiles of stronger lines used to study gas motions, requires a spectral resolution of at least 0.2Å; a resolution of 0.1Å or better is highly desirable. Low-dispersion spectroscopy, on the other hand, serves primarily for observation of faint sources. Observing programs calling for this capability either do not require high resolution for analysis, or they involve sources with intrinsically broad spectral features. In the low dispersion mode SAS-D emphasis, therefore, is on limiting magnitude rather than resolving power.

To achieve the high spectral performance required by the scientific objectives, the SAS-D concept placed great emphasis on the data-gathering efficiency of the instrumentation. Use of an echelle spectrograph with a coarse grating operating at very high spectral order and a cross dispersive element to separate the adjacent orders produces a data format that permits recording the complete spectrum on the face of a television tube.

This technique permits recording of the entire spectrum without rotating a grating or moving the detectors. Television tubes with an efficiency equivalent to that of a photomultiplier tube are available; recent advances in tube design and technology make television tubes fully compatible with space astronomy.

The design also permits easy conversion of the spectrograph to a low resolution mode by inserting a plane mirror in front of the echelle; this effectively changes the resolution of the spectrograph from 0.1Å to 6Å. In this mode, a 30-minute exposure of the spectrograph camera can record a 12th magnitude object, and longer exposures can record even fainter objects.

The telescope associated with this type of spectrograph acts chiefly as a photon collector. Its optical quality need only be sufficient to ensure that all of the light from the target passes through the spectrograph entrance aperture. The telescope has been designed to produce a 1-arc-second-diameter image at the focal plane. The spectrograph entrance aperture is 3 arc-seconds. The spectrograph system, which is simple and reliable, occupies a relatively small volume.

Characteristics of the telescope and spectrograph are:

Telescope	
Type	Cassegrain
Aperture	45 cm
Focal ratio	f/15
Image quality	1 arc-sec
Field camera	10 x 10 arc-min.
Spectrograph	
Type	Echelle
Entrance aperture	3 arc-sec
Wavelength range	1150-3200Å
High dispersion	$R = 1.6 \times 10^4$
Limiting magnitude*	7
Low dispersion	$\Delta = 6$Å
Limiting magnitude*	12
Detector	SEC (secondary electron conduction) vidicon camera
Statistical photometric accuracy	2-5 percent

*Limiting magnitudes estimated for 30m exposure on a B0V star

Figure 1 shows the principal design features of the scientific instrument.

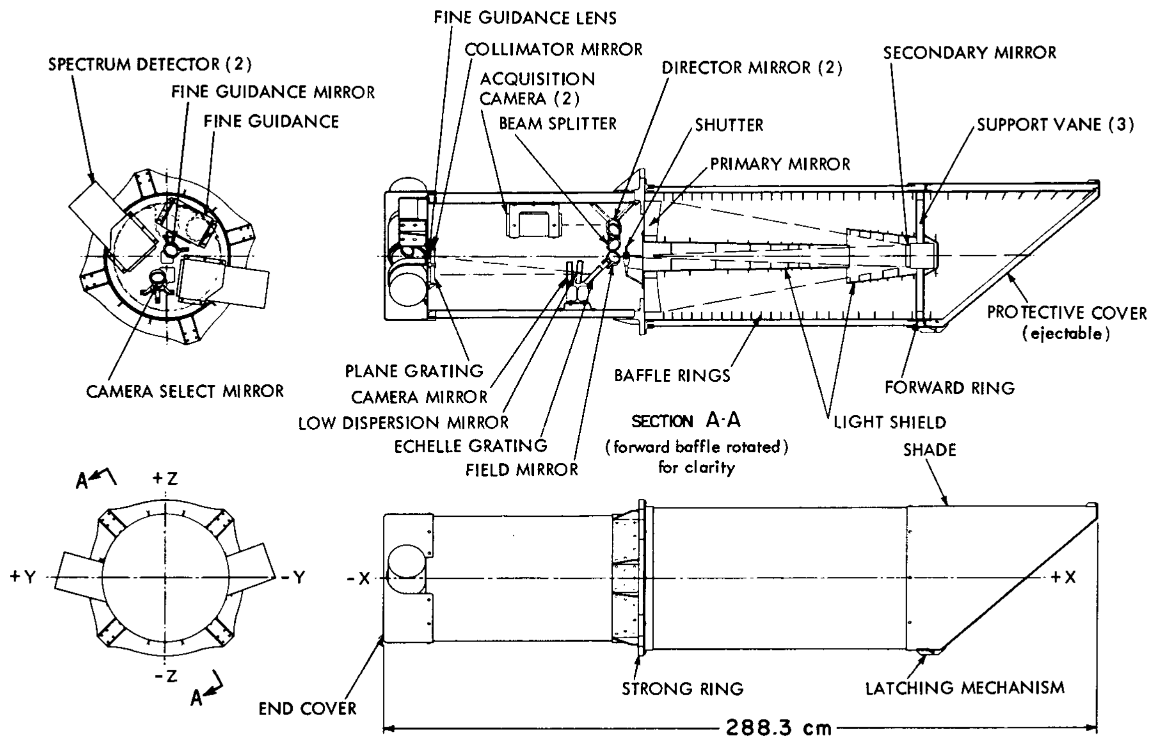

Figure 1. Scientific Instrument Package

2.6 SPACECRAFT

Figure 2 shows the interior and exterior features of the spacecraft. The spacecraft has been designed to provide a telescope platform that can:

- Point the telescope at a target located anywhere in the celestial sphere with an accuracy of ±1-arc-second
- Hold a 1-arc-second-diameter star image within the 3-arc-second-diameter spectrograph entrance aperture long enough to permit an integrated exposure of 0.5-hour duration by the spectrograph camera
- Slew the telescope from one target to another at a rate of 4 or 5 degrees per minute per axis

Cost considerations were a factor in the selection of a synchronous orbit for the satellite. This orbit significantly reduced the size and complexity of the ground system. It simplified the spacecraft system design and in addition, it provided

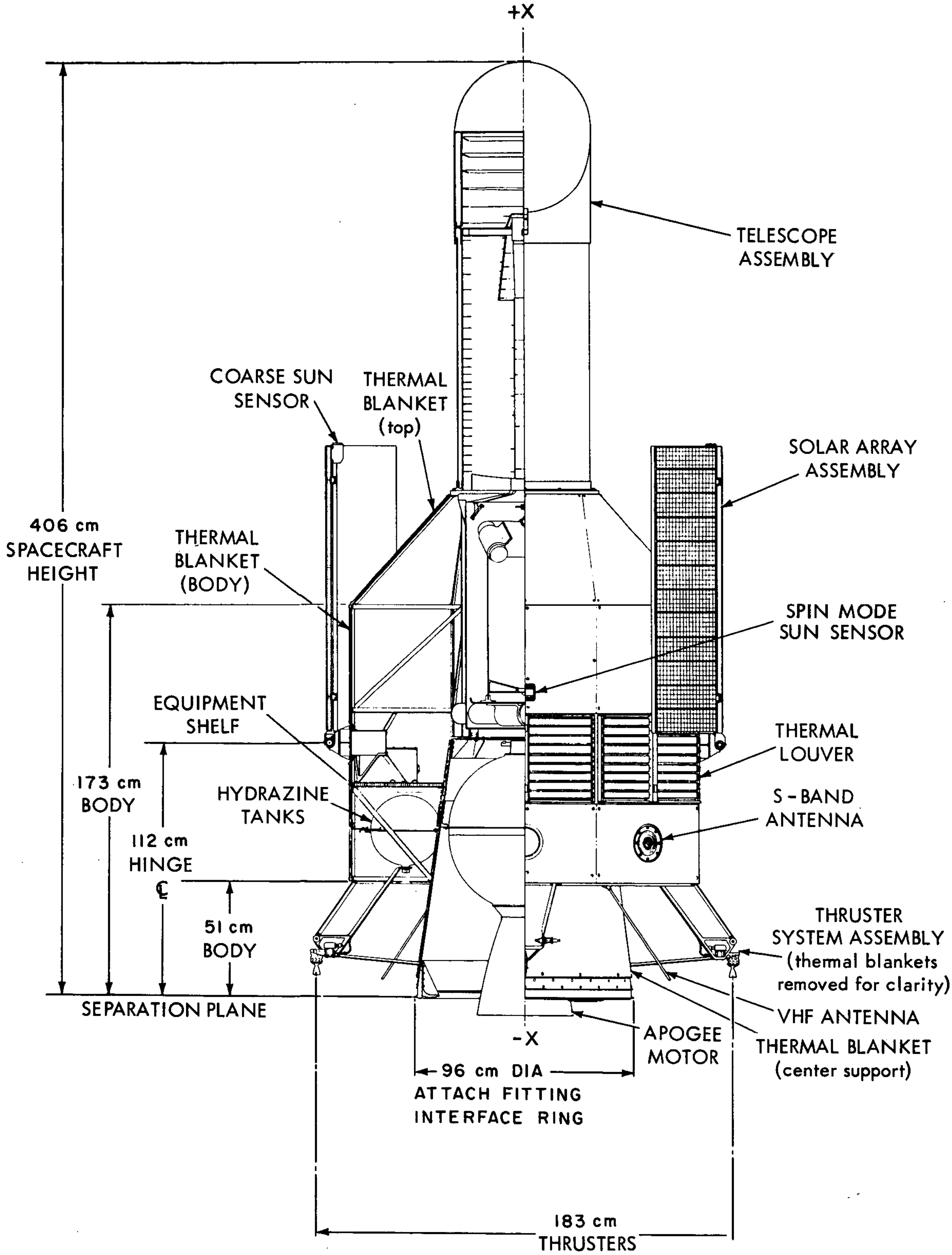

Figure 2. SAS-D Interior and Exterior Features

a near-real-time observing capability. The spacecraft system concept makes extensive use of the continuous spacecraft-to-ground communications capability provided by a synchronous orbit. On a single day, the system can make observations anywhere in the celestial sphere to within 40 degrees of the sun, and the entire celestial sphere is observable within a 3-month period. The spacecraft will have a design-life goal of 3 years and will carry consumables for a 5-year mission. Astronomers can control telescope pointing from the ground with the aid of a ground computer. An acquisition TV camera in the spacecraft will record the star field located in the central 10-arc-minute field of the main telescope, operating like the "finder" telescope used with ground-based telescopes.

A fine guidance system and an inertial reference assembly implemented with gas bearing gyros will hold the telescope on the target star after acquisition. A momentum-exchange system using three conventional reaction wheels arranged in an orthogonal triad will generate control torques. A hydrazine system will provide momentum unloading, stationkeeping, and other propulsion requirements.

The communications system will operate at S-band with a 30-foot ground antenna. An independent VHF command system has been included as a backup. The power system, a modification of the IMP-I design, uses a fixed array and is sized to maintain the spacecraft in a positive energy balance over two-thirds of the celestial sphere. Batteries supply power for operations over the remaining portion of the observable sphere and during the 71-minute eclipse periods. An integrated design using both active and passive elements provides thermal control.

The design included an apogee-insertion motor to place the spacecraft into a geosynchronous orbit from the transfer orbit attained with the Delta 2614. Basic spacecraft weight is 669 pounds; apogee motor weight is 523 pounds. This requires a launch-vehicle capability in excess of 1192 pounds. The 2614 Delta performance capability for the SAS-D mission is 1390 pounds. The 2914 Delta configuration, which will be available in this time period, allows an additional 100 pounds of spacecraft weight contingency.

2.7 LAUNCH VEHICLE

The launch vehicle for the SAS-D mission will be a Delta 2614, on which detailed information appears in the Delta project plan.

The first stage is a McDonnell Douglas Astronautics Company (MDAC) modified Thor booster incorporating six strap-on Thiokol solid-fuel rocket motors. The booster is powered by a Rocketdyne engine using liquid oxygen and liquid hydrocarbon propellants. The main engine is gimbal mounted to provide pitch and yaw control from liftoff to main engine cutoff (MECO). Two liquid-propellant vernier engines provide roll control throughout first-stage operation and pitch and yaw control from MECO to first-stage separation.

The second stage is powered by an Aerojet General Corporation liquid-fuel pressure-fed engine which is also gimbal-mounted to provide pitch and yaw control through second-stage burn. A nitrogen gas system using eight fixed nozzles provides roll control during powered and coast flight as well as pitch and yaw control after second-stage cutoff. Two fixed nozzles, fed by the propellant-tank helium-pressurization system, provide retrothrust after spacecraft separation.

The third-stage is the TE-364-4 spin-stabilized solid-propellant motor manufactured by the Thiokol Chemical Corporation (TCC). The third stage motor is secured in a spin table mounted to the second stage. The firing of two to eight solid-propellant rockets fixed to the spin table accomplishes spinup of the third-stage assembly.

The SAS-D spacecraft will be attached to the Delta third stage by means of a Delta attach fitting that incorporates the separation system.

The Delta 8 foot fairing that protects the spacecraft from aerodynamic heating during the boost flight is jettisoned as soon as the vehicle leaves the sensible atmosphere shortly after second-stage ignition.

An all-inertial guidance system, consisting of an inertial sensor package and digital guidance computer, controls the vehicle and sequence of operations from liftoff to third-stage separation. The sensor package provides vehicle attitude and acceleration information to the guidance computer, which generates vehicle-steering commands to each stage to correct trajectory deviations by comparing computed position and velocity against prestored values.

SECTION 3

WORK PLAN

3.1 GENERAL

The system definition phase effort will consist of a NASA/GSFC in-house study supported by subsystem and component studies to be performed by UK, ESRO, and selected contractors. The acquisition phase is planned as an in-house GSFC program with major elements of the spacecraft and ground system hardware supplied by UK and ESRO. Section 3.2 describes specific study responsibilities assumed by UK and ESRO, and Section 3.3 describes the detailed tasks planned for the system definition phase. These detailed tasks can be divided into four functional groups.

- Spacecraft subsystem design to a level sufficient to write detailed procurement specifications for the flight subsystem components
- Development of functional specifications and initiation of the procurement cycle for long-lead-time components and subsystems (the inertial reference assembly and the hydrazine propulsion subsystem)
- Development of an engineering test unit (ETU) of the spectrograph, telescope, and spacecraft
- Definition of all ground-system hardware and software requirements

The development plan is based on the protoflight concept and calls for construction of two units. One, a complete flyable spacecraft designated the protoflight unit, is manufactured during the acquisition phase. The other, a nonfunctional test unit designated the engineering test unit (ETU), is developed during the system-definition phase. The ETU, complete except for electronic assemblies represented by thermal/mechanical mockups, will support specific design-verification tests in the thermal, structures, and optics areas. It will serve to establish vibration-test levels for component and subsystem testing, to study overall system design, and to optimize the optical, thermal, and structural designs of the instrument.

The protoflight-development concept for the SAS-D spacecraft was feasible because many identical components (or components of a similar design) were either developed for or had flown on other NASA spacecraft; the three major exceptions are the spectrograph, the spectrograph camera and the inertial reference assembly. Handling the development and qualification of these three items separately could eliminate the time and expense of producing a prototype spacecraft and conducting a separate prototype test program.

3.2 INTERNATIONAL COOPERATIVE ARRANGEMENTS

In December 1970, NASA proposed to the UK and ESRO a three-way division of the SAS-D system definition phase efforts:

- NASA will be responsible for conducting overall system studies and will be responsible for the spacecraft (except for solar arrays), the telescope and shade, spacecraft integration and test requirements, launch-vehicle interfaces, and orbit operations.

- UK will study spectrograph image tubes, including calibration and test requirements.

- ESRO will study the acquisition camera, the fine guidance sensor, and the solar arrays, and will assist NASA with thermal analysis of the spacecraft.

- ESRO will examine the possibility of providing a European-based ground station.

The UK has committed the resources necessary to execute its responsibilities for the system definition phase studies. ESRO has reviewed the NASA proposal and has recommended participation in the SAS-D program on the following basis:

- Negotiate a spacecraft hardware contribution up to a maximum of one million dollars

- Joint participation with UK in constructing a European-based ground station

ESRO has funded the system-definition phase studies associated with establishing a European-based ground station. Informal discussions between NASA and ESRO have identified the solar arrays and other elements of the power subsystem as those hardware elements most likely to fit within ESRO's funding and schedule guidelines. An informal definition of ESRO's specific spacecraft tasks is expected by the fall of 1971. A formal memorandum of understanding between NASA and ESRO, and NASA and UK, should be executed before January 1972 in order to permit all three partners to identify the resources required for the acquisition phase and to phase these activities into the normal yearly budget cycle.

3.3 DETAILED SYSTEM DEFINITION PHASE TASKS

The system definition phase tasks represent a continuation of the analytical work that established the overall feasibility of the project. The system concept derived from that analytical work is defined in the Phase A (mission definition phase) technical report. System definition phase activities will include detailed engineering analysis and breadboarding necessary to select a single project approach from the feasible approaches. Unless otherwise noted, all tasks are the responsibility of NASA/GSFC.

3.3.1 SCIENTIFIC INSTRUMENT

Major scientific instrument tasks during the system definition phase are:

- An analytical study of the optical system proposed in the mission-definition phase for the telescope and spectrograph, to weigh the merits of the proposed design against alternative designs, taking into account considerations of space, weight, cost, image quality, fabrication, assembly, testing, alignment, and optical, mechanical, and thermal tolerances. Principal design alternatives to be considered are type of telescope (Cassegrain, Dall-Kirkham, or Ritchey-Chretien), focal ratio of the telescope (f/15 or f/9), type of spectrograph (four-mirror, three-mirror, or prism-type), readout format (single or double). The end product of this study will be a final detailed design from which manufacturing specifications can be developed.

- An evaluation of TV camera tubes suitable for the spectrograph camera, to provide a basis through tradeoff studies for selection of a camera tube that will result in an optimum spectrograph camera system with regard to weight, power, reliability, and overall performance of the combined optical and camera systems. Functional characteristics to be determined are quantum efficiency, target transfer function, dark current, geometric distortion, and resolution. Preliminary environmental tests will be performed and life tests will be started. The evaluation will result in selection of a single tube type for the spectrograph camera. U.K. has prime responsibility for this task.

- An evaluation of TV camera tubes suitable for use in the acquisition-camera system. One tube type will be selected for the flight-system design. Work to be done under this task is similar to that described for the spectrograph camera and will require a similar test routine. The results of this effort and the evaluation of a UV converter will provide a back-up spectrograph camera design.

- Evaluation of fine guidance sensors and system design and selection of the system to be used on SAS-D. Two systems emerged from the Phase A study as prime candidates: the vibrating-reed system and the image-dissector system. System-definition phase work will provide data on the two systems to permit a selection.

- Further refinement of the thermal model by analytical study of thermal considerations bearing on the SAS-D instrument configuration; design of thermal-control hardware for the instrument

- Structural design and analysis resulting in a detailed structural design; design of all mechanisms

- Fabrication of components for the engineering test unit of the scientific instrument

3.3.2 SPACECRAFT

Major tasks of the spacecraft to be undertaken during the system definition phase are:

- Completion of the attitude-control system design; breadboard critical elements and completion of the inertial reference assembly design. Several gas-bearing gyros will be evaluated in a single-axis closed-loop system. Information derived from this evaluation will be used in establishing the control-system design and developing manufacturing specifications.

- Definition of requirements for the onboard attitude computer. Evaluation of a commercial machine for its capabilities relative to SAS-D requirements. Tradeoff studies to determine optimum combination capabilities and requirements

- Completion of communications and data-handling system design; breadboard critical parts and generate specifications and requirements for data-handling/experiment interface

- Detailed design of spacecraft electrical system

- Detailed design of spacecraft structure and mechanisms; fabrication of engineering test unit hardware
- Study of hydrazine propulsion-system designs
- Detailed power-system design: start special battery life test program; studies of radiation effects on solar cells; sizing and configuration of solar array
- Development of a detailed analytical thermal model
- Definition of optical, structural, and thermal testing requirements, and of environmental test requirements. Establishment of test plans and procedures for the Engineering Test Unit and for flight components, instrument, and spacecraft
- Continuation of mission analysis studies started during Phase A to determine mission constraints, launch windows, navigation errors, fuel requirements, and tradeoffs of various geostationary orbits, together with necessary attitude determination studies
- Establishment of a reliability assurance program plan

3.3.3 GROUND SYSTEMS

System definition phase efforts will consist of further project definition of the ground systems, in cooperation with UK, ESRO, and the GSFC Mission and Data Operations and Networks Directorates. The SAS-D spacecraft will be launched from Eastern Test Range (ETR) on a Delta launch vehicle. During transfer orbit, the following stations will provide tracking data: Guam, Rosman, Alaska, Goldstone, Hawaii, Madrid, Carnarvon, Tananarive, and Santiago. Tracking data transmitted to GSFC will be used to produce the orbital elements, station predicts, and predicted orbit data. Merritt Island Unified S-band Station (MIL-USB) will support the geosynchronous satellite 24 hours a day for the life of the spacecraft. Specific tasks are:

- Definition of specific responsibility for the U.S., UK, and ESRO in developing the overall ground system and communications network
- Definition of the dedicated GSFC network station and the communications link to the U.S. observatory (Operations Control Center)
- Definition of all facilities required to establish the U.S. observatory

- Establishment of a software development plan for spacecraft integration, image processing, spacecraft control, mission analysis and orbit attitude support

- Evaluation of the Jet Propulsion Laboratory (JPL) image-processing system

- Sizing of the computer to determine if all processing can be handled by the U.S. observatory computer

- Evaluation of alternate data-processing system concepts

- For MIL-USB station, the 40.96 kbps split-phase telemetry will be considered for Radio Frequency (RF) margin calculation using bep of 10^{-6}.

- The Network Directorate will assess the necessary modifications for the second antenna system at the MIL-USB station and develop a schedule to accomplish this task including the NASCOM wideband capability that interfaces the MIL-USB station with the U.S. observatory.

3.4 CRITICAL DECISIONS

SAS-D studies have revealed no technical problem areas beyond the state-of-the-art critical to the success of the mission. The following are some of the major events critical to a SAS-D launch in the second half of calendar year 1975. These are decisions, approvals, and agreements that may delay the schedule if they do not occur on time:

ACTION	DATE
• GSFC Facilities Planning Committee decision on space requirements for observatory	Nov. 1971
• Signing of US/UK/ESRO memorandum of understanding	Jan. 1972
• Headquarters approval for release of RFP's for the development of flight hydrazine propulsion subsystem	Mar. 1972

ACTION	DATE
• Headquarters approval for release of RFP for inertial-reference assembly flight units on basis of planning PR	Mar. 1972
• Headquarters approval of the acquisition phase revision of the project plan	June 1972
• Acquisition phase funding	July 1972
• Delivery of breadboard model of Spectrograph camera system by UK	Jan. 1973
• Commitment for MIL-USB second antenna system for downtime to implement the station modifications	Jan. 1974
• Modifications of MIL-USB for SAS-D	May 1974
• VHF command antenna relocation to MIL-USB station (if required)	May 1974
• Network training program	Sept. 1974
• Negotiate lease contract for wideband communications link	Apr. 1975

3.5 ART-SRT

The SAS-D project has not depended on any ART-SRT effort to date, nor is any such dependence anticipated.

3.6 FACILITIES

The SAS-D project requires the use of major NASA facilities during fabrication, integration, test, checkout, launch, and postlaunch operations. Table 2 shows the SAS-D facilities requirements.

Table 2

SAS-D Facilities Requirements

Description	Location	Earliest Date Required	Duration
Engineering Test Unit			
Vibration	GSFC	April 1973	2 weeks
Thermal-vacuum	GSFC	April 1973	3 weeks
Balance	GSFC	March 1973	1 week
Flight Spacecraft			
Vibration[1]	GSFC	May 1975	2 weeks
Thermal-vacuum test[1]	GSFC	May 1975	3 weeks
Balance	GSFC	April 1975	1 week
Network compatibility	GSFC	March 1975	2 weeks
Scientific Instrument			
Vacuum optical bench[1]	GSFC	March 1973	2 weeks
Low temperature optical facility[1]	GSFC	March 1973	2 weeks
Launch site for Delta	ETR	August 1975	As req'd
Satellite tracking during transfer orbit	Stations as req'd	August 1975	Operational
Observatory Control Center[2]	GSFC	September 1974	Operational 24 hrs/day
Telemetry Acquisition. 30-foot dedicated antenna.	MILA	September 1975	Operational 24 hrs/day
Spacecraft attitude & orbit computation	GSFC	September 1975	Operational

1. Clean facility (Class 10,000 or better)
2. See critical decisions

SECTION 4

MAJOR SUPPORT INTERFACES

Major support interfaces during the system definition phase, other than within NASA or with NASA contractors, are limited to those resulting from the parallel work of the UK and ESRO. Figure 6 shows the organizational interfaces between GSFC and the UK and ESRO for the system definition phase.

The primary coordination of the international effort is through the designated UK, ESRO, and GSFC project managers. On the project support level, UK and ESRO scientific instrument managers work directly with their GSFC counterpart. Similarly, European ground-station development will be carried out with a technical interface between the European ground operations systems manager and the GSFC mission operations systems manager.

Because specific spacecraft hardware responsibilities have not yet been defined for ESRO, the technical interface for this area remains through the project managers.

The SAS-D project office will coordinate the interfaces between the UK and ESRO and the work being done at GSFC and by GSFC contractors.

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SECTION 5

PROCUREMENT

5.1 SYSTEMS DEFINITION PHASE PROCUREMENTS

Goddard will carry out its portion of the system definition phase as an in-house effort and expects no single procurement greater than $100K. Several small procurements each less than $100K will support specific definition studies and purchase critical components for evaluation. See Fig. 3.

5.2 ACQUISITION PHASE PROCUREMENTS

The acquisition phase is planned as an in-house effort that will require long lead procurement initiation for the inertial-reference assembly, the apogee motor, the hydrazine-propulsion system, and the onboard computer. See Fig. 4

Anticipated procurements for this phase are:

No. of Contracts	Dollar Value Range	PR Initiation	Contract Award
28	$100K - $1M	Jul to Aug 72	Feb to Apr 73
1	1M - 2.5M	11/71[1]	11/72
1	Over 2.5M	1/72[1]	1/73

The $1M-$2.5M contract is for the hydrazine-propulsion system. The over-$2.5M contract is for the inertial reference assembly. Both of these procurements will be on a competitive basis, but the type of contract is unknown at this time.

1. See critical decisions

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SECTION 6

SCHEDULES

Figure 3 is the milestones schedule for the system definition phase. Figure 4, the overall project schedule shows major milestones for the entire project.

2 YEAR

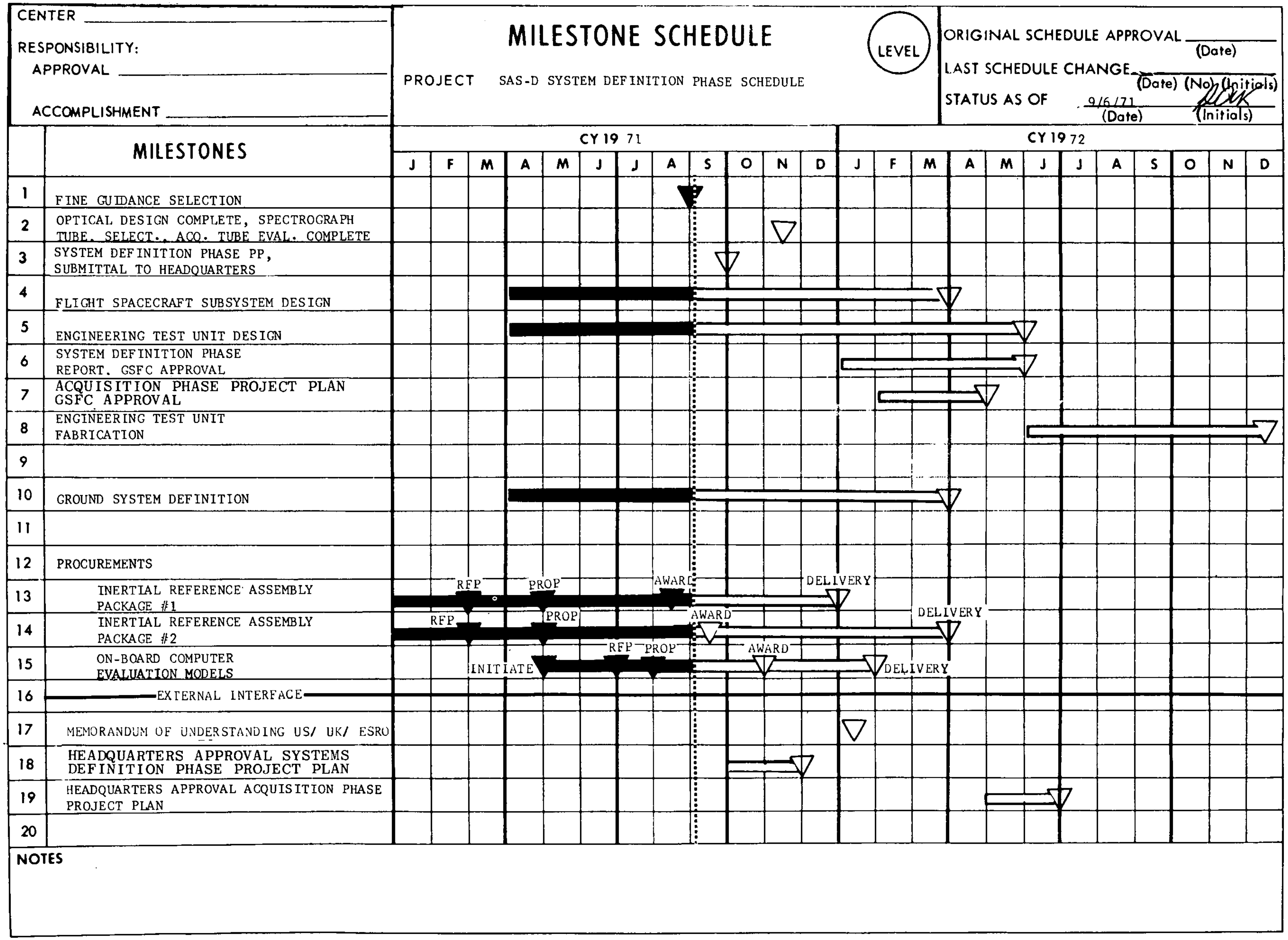


Figure 3. SAS-D System Definition Phase Schedule

CENTER ______

RESPONSIBILITY:
APPROVAL ______

ACCOMPLISHMENT ______

MILESTONE SCHEDULE

LEVEL

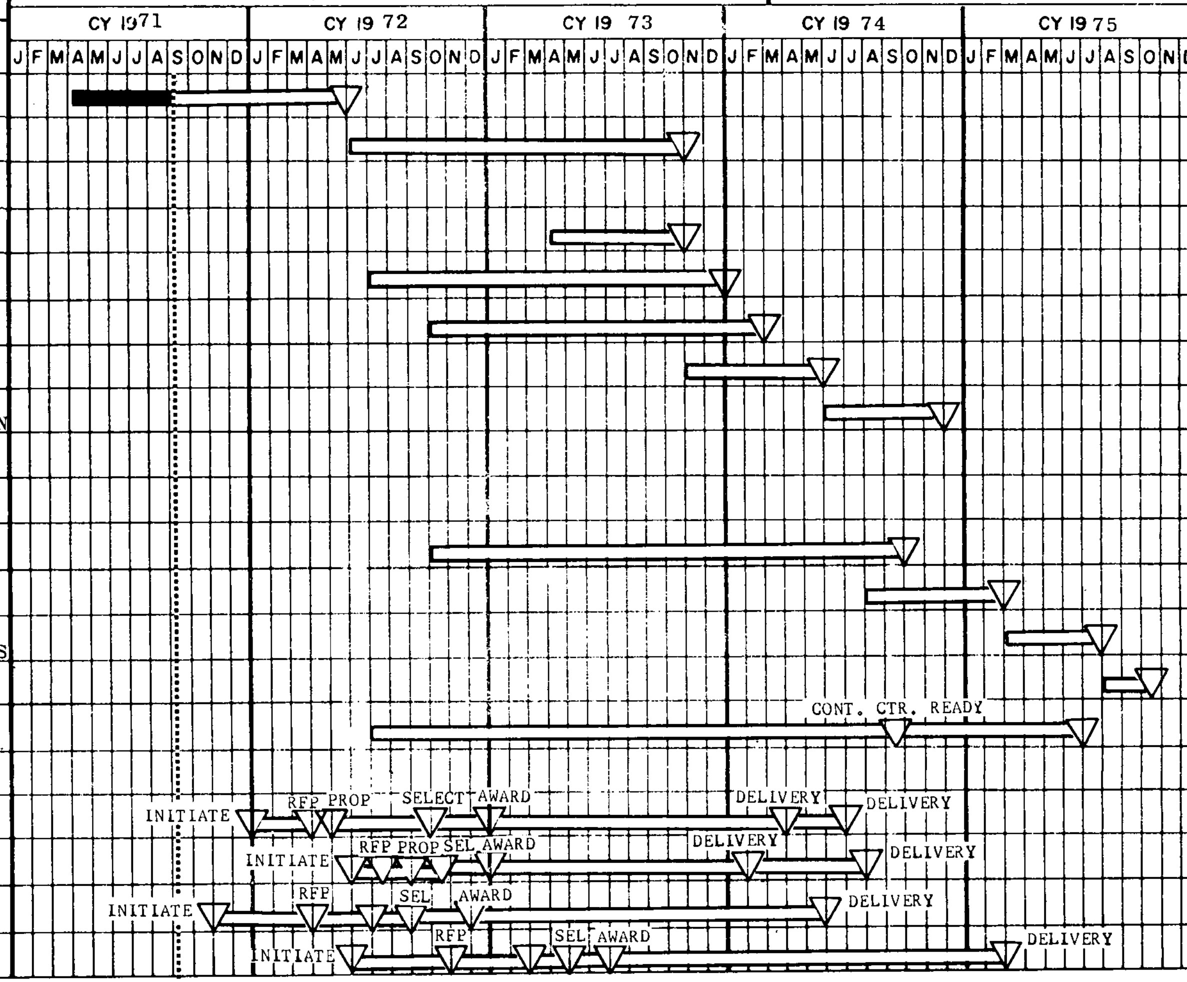
PROJECT SAS-D PROJECT SCHEDULE

ORIGINAL SCHEDULE APPROVAL ______ (Date)

LAST SCHEDULE CHANGE ______ (Date) (No) (Initials)

STATUS AS OF 8/27/71 (Date) (Initials)

	MILESTONES
1	SYSTEM DEFINITION STUDIES
2	ENGINEERING TEST UNIT FABRICATION, ASSEMBLY, TESTING
3	FLIGHT SCIENTIFIC INSTRUMENT
4	STRUCTURE FABRICATION
5	SPECTROGRAPH CAMERA SYSTEM DEVELOPMENT (UK)
6	ACQUISITION CAMERA SYSTEM DEVELOPMENT
7	ASSEMBLY & ALIGNMENT
8	ACCEPTANCE TEST & CALIBRATION
9	
10	
11	FLIGHT SPACECRAFT SUBSYSTEMS DEVELOPMENT
12	FLIGHT SPACECRAFT INTEGRATION
13	FLIGHT SPACECRAFT ACCEPTANCE TESTS
14	LAUNCH OPERATIONS
15	GROUND SYSTEM READINESS
16	LONG-LEAD PROCUREMENTS
17	INERTIAL REFERENCE ASSEMBLY FLIGHT UNITS
18	ON-BOARD COMPUTER FLIGHT UNITS
19	HYDRAZINE PROPULSION SYSTEM
20	APOGEE KICK MOTOR



NOTES

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Figure 4. SAS-D Project Schedule

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SECTION 7

RESOURCES

Funds to support in-house study efforts in both the FY 71 and FY 72 were provided under the general SAS-unique project code of 878-2X. A total of $400K used in FY 71 to support in-house study efforts funded a thermal and an optical study as well as the procurement of camera tubes and gyros to be tested and evaluated at GSFC for systems development.

7.1 SYSTEM DEFINITION PHASE

A total $1M 506 authority has been received to support the system definition phase studies in FY 72. Of the $1M budgeted, approximately $600K will go for design and development of the engineering test unit of the scientific instrument. This effort will include optical, thermal, and structural analytical studies leading to fabrication of the ETU instrument optics and structure. The remaining $400K will support the development of long-lead-time items, including the spectrograph and acquisition cameras, the onboard computer, the inertial reference assembly, and sensors for the fine guidance system. Direct manpower requirements for the system definition phase in FY 72 are:

GSFC System Definition Phase (FY 72) Direct Manpower

Directorate		Man-Years
200	Administration & Management Directorate	0.1
300	Systems Reliability Directorate	1.6
500	Office of the Director of Mission and Data Operations	3.0
600	Space & Earth Sciences Directorate	12.7
700	Space Applications & Technology Directorate	29.3
800	Office of the Director of Networks	0.1
	Total	46.8

7.2 ACQUISITION PHASE

Cost and manpower submitted for the acquisition phase, as shown in Table 3, are based on information obtained from grass-roots resources estimates. Based on 1971 dollars, funding of $30.0M, including an $8.5M contingency, and 606 man-years of direct in-house civil service effort will be required to complete the acquisition phase. Consideration of a 5% inflation factor would indicate a $34M estimated cost through project completion. This cost estimate does not include ground operations costs (observatory operational costs are funded through OTDA; data analysis costs will be funded by the sponsoring institution) or the cost of systems to be supplied by UK and ESRO.

Table 3

SAS-D Acquisition Phase Resources Requirements

	FY73	FY74	FY75	FY76	To Compl.	Total
Grass-Roots Funding Estimate (in millions)	8.5	7.5	4.3	1.0	0.2	21.5
Contingency	0.5	0.5	2.7	4.0	0.8	8.5
Total Project Estimate	9.0	8.0	7.0	5.0	1.0	30.0
Direct Civil Service Manpower (in man-years)	140	172	156	72	66	606

Table 4 is an estimate of the net worth to NASA of the program contributions expected from the UK and ESRO.

Table 4

Cost Sharing (millions of dollars)

	Spacecraft Hardware	European Ground System*
UK	3-4	
ESRO	1.0	3-4
	4-5	3-4

*A European ground station will not be built if ESRO and the UK do not participate in the program.

Resource estimates for the acquisition phase will be reviewed and updated at the completion of the system definition phase. The revised estimates will appear in the revision of the project plan scheduled for submission to NASA Headquarters in the spring of 1972.

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SECTION 8

MANAGEMENT PLAN

8.1 ORGANIZATION AND ASSIGNMENTS

Management responsibilities and procedures for the SAS-D project will be implemented in accordance with NHB 7121.2, Phased Project Planning Guidelines; NMI 7120.1, dated May 4, 1970, Implementation of OSSA Instruction on Approval and Implementation of OSSA R&D Programs; GMI 7121.1A, dated August 11, 1970; and the June 1971 report, Management Study of NASA Acquisition Process.

The Associate Administrator for Space Science and Applications (OSSA) has assigned overall Headquarters responsibility for this program to the Director of Physics and Astronomy Programs, J. Mitchell. The Director of Physics and Astronomy Programs has designated Dr. N. Roman as program scientist and J. Holtz as program manager. Mr. Holtz is the primary point of contact in Headquarters for all matters relating to the program. Within NASA, the Goddard Space Flight Center (GSFC) has been assigned responsibility for management of the project.

Within GSFC, the SAS-D project office is located in the Space Applications and Technology Directorate. Figure 5 shows the SAS-D project staff interface with GSFC directorates and facilities; Figure 6 is a chart of the SAS-D project management organization for the system definition phase; it will be revised for the acquisition phase.

8.1.1 ACTING PROJECT MANAGER

D. Krueger, acting project manager, is responsible for the direction, organization, and staffing necessary to conduct the SAS-D system definition phase study. His duties involve projectwide planning, evaluation, systems integration, system safety, systems engineering, scheduling, reporting, and fiscal and contract monitoring. He reviews actions that interface with other agencies or organizations and represents the Director, GSFC, in matters pertaining to the project. He has full authority to carry out these functions, subject to limitations established by the Director, GSFC. He discharges his duties with the support of individuals and organizations composing the SAS-D project management organization as integrated with the functional GSFC organization.

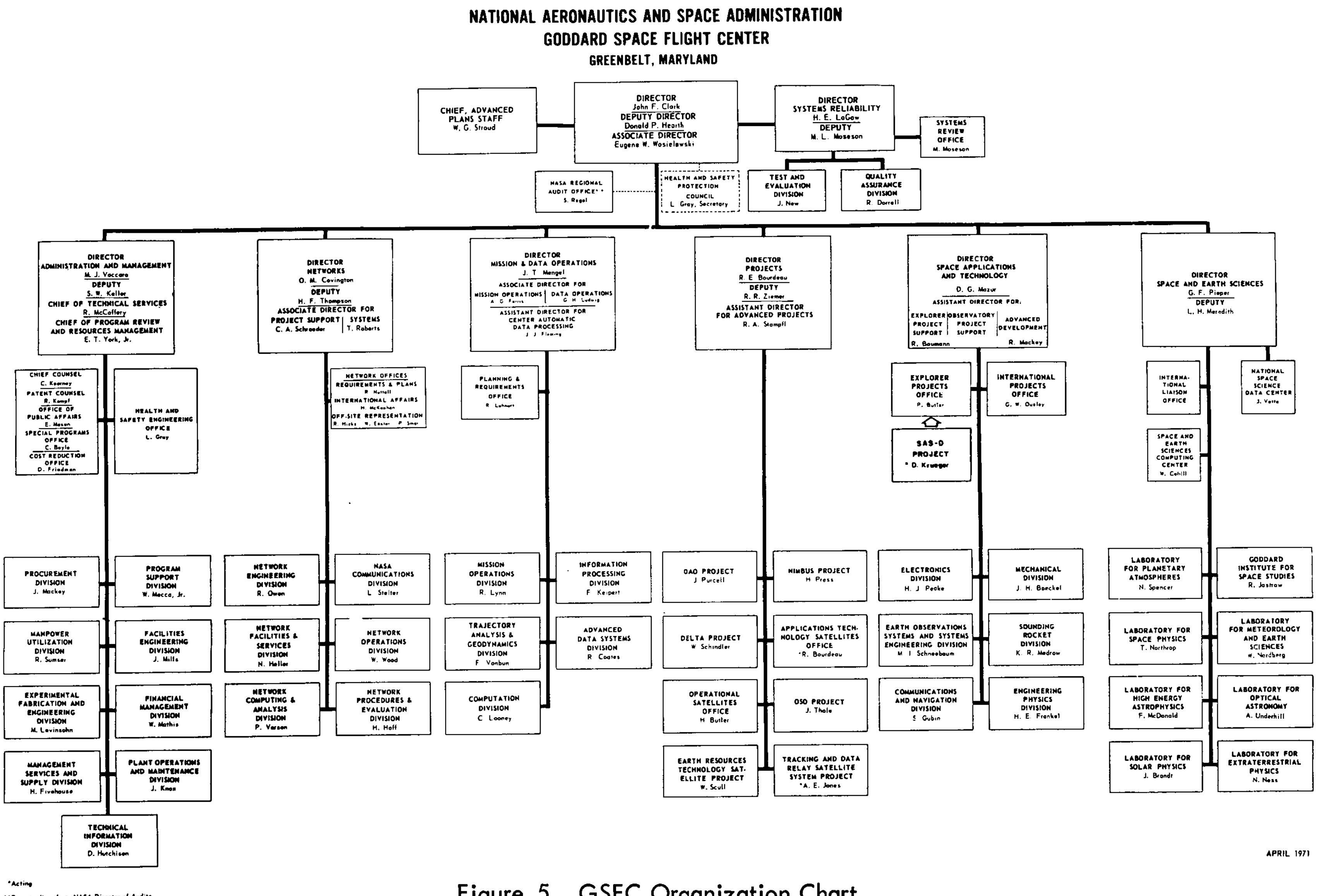

Figure 5. GSFC Organization Chart

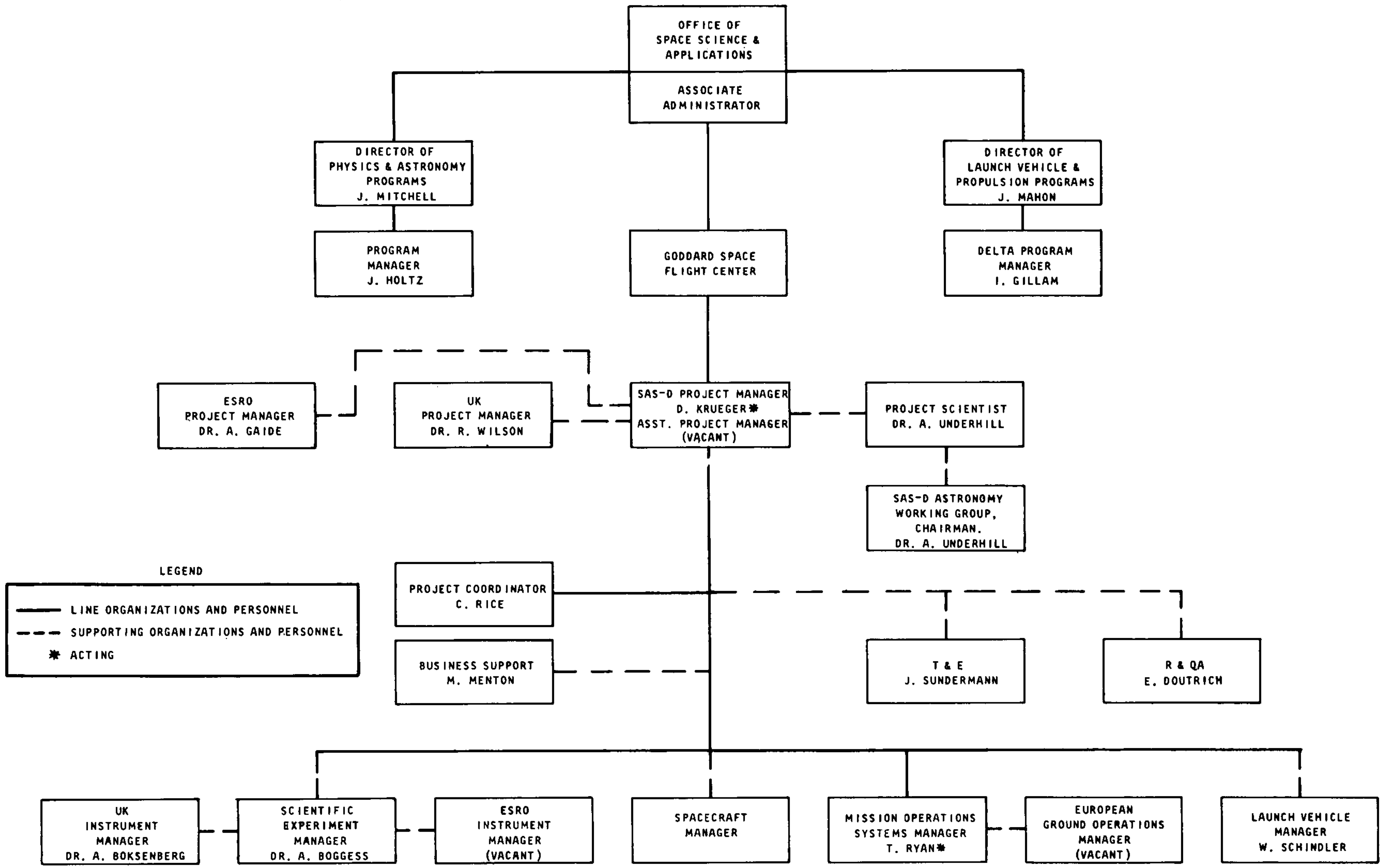

Figure 6. OSSA/GSFC Project Management Organization Chart for SAS-D (System Definition Phase)

8.1.2 PROJECT SCIENTIST

Dr. A. Underhill, Space and Earth Sciences Directorate, project scientist, is responsible for assuring coordination and compatibility between the scientific objectives of SAS-D and the scientific instrument. She evaluates all scientific guidance to the project manager and others involved in the program.

8.1.3 SAS-D ASTRONOMY WORKING GROUP

The SAS-D Astronomy Working Group advises the project scientist on all matters pertaining to the ultimate capability and use of the SAS-D spacecraft and ground system. This group, chaired by Dr. A. Underhill, GSFC, is a broad-based body representative of the astronomy community (see Section 2.4); the primary function of this group is to ensure that the scientific objectives of SAS-D are congruent with the interests of the astronomy community within the basic constraints of the SAS-D concept.

8.1.4 ASSISTANT PROJECT MANAGER

The assistant project manager assists the project manager in performing all SAS-D management functions. He has full authority to carry out functions of the SAS-D project manager with respect to the SAS-D project, subject to limitations established by the project manager.

8.1.5 EXPERIMENT MANAGER

Dr. A. Boggess, Space and Earth Sciences Directorate, scientific instrument manager, is responsible for technical management of the development effort required for the scientific instrument. In this capacity, he coordinates the UK and ESRO scientific instrument tasks with the overall system development taking place at GSFC.

8.1.6 SPACECRAFT MANAGER

The spacecraft manager is responsible for ensuring the performance of all activities necessary to the design and development of all spacecraft systems, excluding the scientific instrument.

8.1.7 PROJECT COORDINATOR

The project coordinator, C. Rice, is responsible to the project manager for coordinating the activities of the various individuals and organizations involved in the project. Duties and line of authority are responsive to the project manager's requirements.

8.1.8 MISSION OPERATIONS SYSTEMS MANAGER

Mr. T. Ryan, acting mission operations systems manager, is responsible to the project manager for all OTDA support provided to the project. As a member of the project staff, he is responsible for the total ground systems support integrity including validating and generating project requirements, assuring adequate resources are committed and overviewing the implementation of the ground system which consists of network, operations control center, orbit and attitude computing system, central processing/data analysis system. Mr. Ryan receives support from the Networks Directorate through Mr. R. Cortez, the networks support manager (NSM) and as the mission support manager (MSM), Mr. Ryan is responsible for the support provided to the project by the Mission and Data Operations Directorate.

8.1.9 LAUNCH VEHICLE MANAGEMENT

W. R. Schindler of the Projects Directorate, GSFC, the Delta project manager, represents GSFC in all matters pertaining to the Delta project. He is responsible for projectwide planning and evaluation, systems integration, systems engineering, scheduling, budgetary and financial planning and management, contract managing, and project reporting.

8.1.10 TEST AND EVALUATION

J. Sundermann, Systems Reliability Directorate, test and evaluation representative, is responsible for establishing all the environmental requirements of the mission from launch to orbital operations. He will recommend and define test limits, requirements, and plans for all phases of the mission, and will participate in any other area that requires test and evaluation inputs for project planning and study. He will provide support to the project to satisfy all environmental and special optical test requirements.

8.1.11 RELIABILITY AND QUALITY ASSURANCE

E. Doutrich, Systems Reliability Directorate, the reliability and quality assurance support representative, assists and advises the project manager to assure proper emphasis on quality and reliability considerations throughout all phases of the project. With support from other members of the project staff, he will develop a reliability assurance program plan that will define R&QA requirement tasks necessary to assure the reliability and quality of the spacecraft and its subsystems and experiments.

8.1.12 BUSINESS SUPPORT

The business support representative, M. Menton, Administration and Management (A&M) Directorate, ensures full use of A&M resources in support of project problems and needs. He provides a single point of liaison for all A&M support to the project, and is administratively responsible for all functional A&M activities (scheduling, procurement budget, financial, manpower analysis, organization) and other related A&M support.

8.2 PLANNING DOCUMENTS

8.2.1 BUDGET REPORTS AND REVIEWS

The project manager is responsible for preparing semiannual estimates of resource requirements for the duration of the project effort. He makes a comprehensive review of the status of the project based on GSFC grass-roots calls. In April and November, he will recommend appropriate revisions to the currently authorized budget. The revisions will be distributed in August and February. The regularly scheduled resource estimates and financial reports do not relieve the project manager of the responsibility for submitting change recommendations in resources allocations whenever he feels that these resources are inconsistent or incompatible with the present progress of ultimate success of the project.

8.2.2 PROJECT AUTHORIZATION AND RESOURCES CONTROL

Authorization, planning, and control of this research and development project, and the resources related thereto are in accordance with NASA Management Instruction NMI 7100.4, Authorization and Control of Research and Development Programs, Projects, Other Activities, and Resources Related Thereto.

8.3 PROGRESS REVIEWS

The project manager upon request makes presentations to the GSFC Management Council, a group chaired by the Center Director and composed of top GSFC management officials. Each report covers all significant study aspects including technical progress and management areas such as funding, manpower, and procurement, with emphasis on problem areas and the measures necessary to resolve them.

8.4 SYSTEM DEFINITION PHASE OUTPUT

- Detailed system design

- Analytical report

- Final spacecraft configuration
- Engineering test unit of the spacecraft, telescope and spectrograph
- Project plan revision for acquisition phase
- Ground system definition

8.5 ASSURANCE FUNCTIONS

A reliability and quality assurance program will be defined for the SAS-D project. This R&QA program will be responsive to applicable portions of NASA-wide R&QA publications and to Goddard management instructions, as tailored to suit the particular needs of the SAS-D during subsequent phases of design, fabrication, and testing, and especially in the intended mission and associated operations.

8.6 SAFETY

8.6.1 BASIC REQUIREMENTS

Clause 86 of GSFC Procurement Instruction 146-69, Addendum 3, in implementation of NASA PR 1.5204 will be imposed on contractors.

8.6.2 SYSTEMS SAFETY

The SAS-D project will develop and implement a systems safety program in compliance with the policies and guidelines set forth in NHB 1700.1, Basic Safety Requirements, and the pertinent volumes of the NASA Safety Manual. The project office will prepare and implement a systems safety plan, in conformance with the format outlined in attachment 1 of letter to NASA Headquarters from Office of the Director, GSFC, dated August 10, 1970, Subject: Flight Project Safety Activities at GSFC.